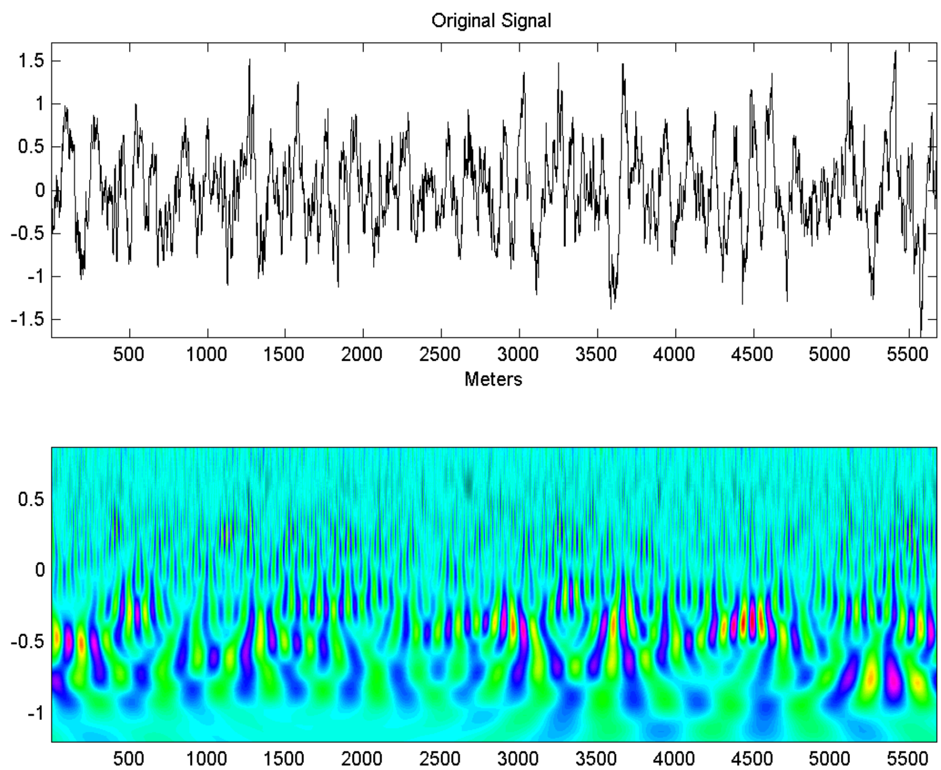
Preliminary Wavelet Analysis of LongEZ Flights from November 1998

By Steven A. Bailey

1/7/99



This report specifically looks at a flight line from November 2, 1998 onboard the LongEZ out of Manteo, NC. The file **'longez_samp.nov2.ts.bin'** was received by Doug Vandemark and I subsequently converted it from the Sun to the PC with a program called 'sun2pc.m' in Matlab. I then created a file called '**longez_samp.nov2.ts.bin.pcformat.mat'**. Within it are 11 fields per record as follows:

Index	Variable	Description
0	phi	2D tilt angle azimuth direction WRT N (radians)
1	tilt	2D tilt angle (radians)
2	SSH	Sea surface height (meters)
3	Ka_band	ka sigma0 (db)
4	theta(*)	Local facet tilt angle (radians)
5	dls(1,*)	Radar pointing angle (radians)
6	y.alt	Aircraft altitude (meters)
7	tilt_1Dcross	Cross-track surface tilt (radians)
8	tilt_1Dalong	Along-track surface tilt (radians)
9	flag	flag=1 when one of the lasers is suspect
10	distance	Along track distance in file (meters)

Wavelet analysis was performed solely on 'Sea surface height' (**SSH**). The wavelet of choice was the Morlet wavelet (Figure 1). It is a modulated gaussian of the form:

$$w(t) = e^{-iw_0 t} e^{-t^2/2}$$

The Morlet is used both because it is symmetrical in shape and because it acts as a smoothing function when applied to data. I used a Matlab program written by Dr. Bertrand Chapron called 'mtrans.m'. This program computes a continuous wavelet transform (CWT) using the Morlet wavelet.

The **SSH** variable is 4479 elements in length and is a time series sampled at 50 Hz. I re-sampled **SSH** into a 'distance' series using the **distance** variable. The final result was a series of 5675 elements in length expressed in distance vs. sea surface height. Resolution is approximately 1 meter.

I decomposed this 'distance' series into 56 scales from octave -4 to 2. There are 8 voices per octave (Figure 2). I then computed the relative energy per scale by finding the mean of the absolute value of the real wavelet coefficients or in Matlab:

```
RE = mean( abs( real(w) ) );
```

Figure 3 shows there are 4 areas of interest for the **SSH** variable. There seems to be ocean swell components at scales 9, 15, and 21. The wind component is likely at scale 38 based on its wavelength of 30 meters.

Figures 4-7 are plots of the real wavelet coefficients at scales 9, 15, 21, and 38. The respective wavelengths at these scales are 400m, 250m, 140m, and 30m.

Beginning with Figure 8, there are a series of plots where I calculate the phase of a particular scale and then average the appropriate real components of an opposing signal. In the case of Figure 8, I move along the series calculating the phase from scale 21 and then averaging the real coefficients at that phase for scale 9. As expected, Figure 10 shows that this calculation is correct.

Figures 13-15 show the relationship between phase of scales 15, 21, and 38 with the radar variable. Figure 15 shows a strong correlation between scale 38 phase and radar. Remember, we assumed scale 38 corresponds to the wind component.

Figures 16-18 show the relationship between phase of scales 15, 21, and 38 with the 2D tilt angle variable. Figure 17 possibly shows a correlation between scale 21 phase and tilt angle at 250 degrees of phase.

Figure 19 is a 'scalogram' of our real wavelet coefficients. It was calculated by taking the power spectra across all 56 scales at each interval in the series. In other words, we end up with 5675 spectra…a spectra across all scales at each point (meter) in the series. As expected, each spectra looks approximately like Figure 3.

Figures 20-22 are a calculation of phase angle from scales 15, 21, and 38 vs. the calculated slope of scalogram scales 23 trough 28. This slope was found from the second coefficient of a 1^{st} order least squares fit. I see no correlation.

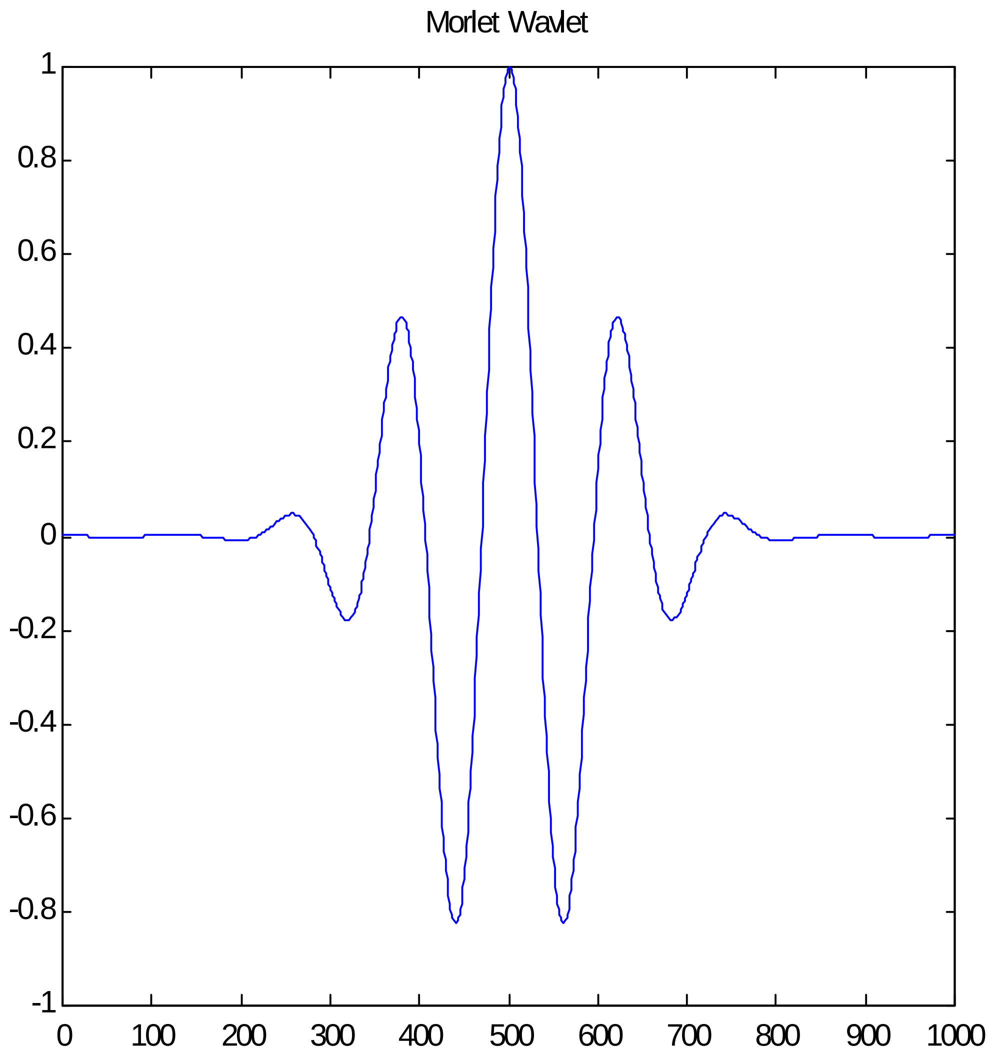

Morlet Wavlet
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
100
200
300
400
500
600
700
800
900
1000

Figure 1

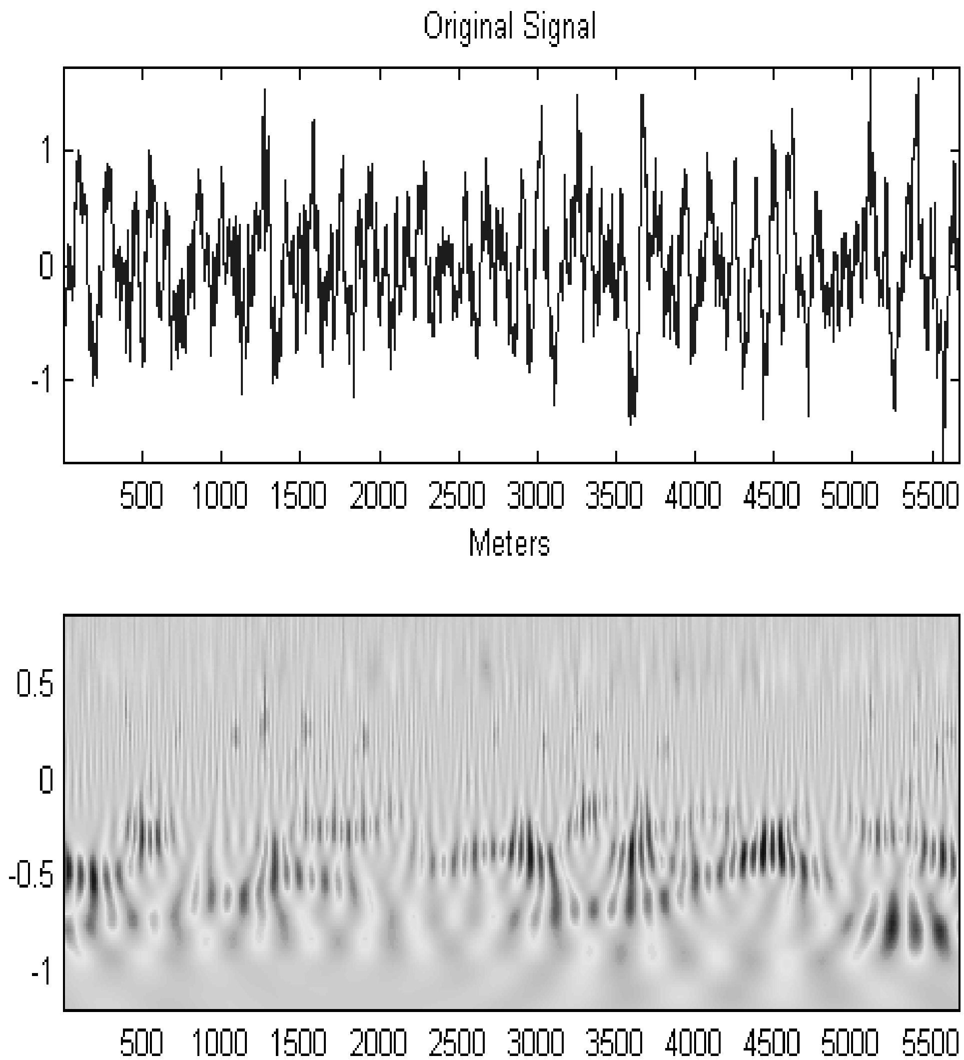

Original Signal
1
0
-1
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
Meters
0.5
0
-0.5
-1
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500

Figure 2

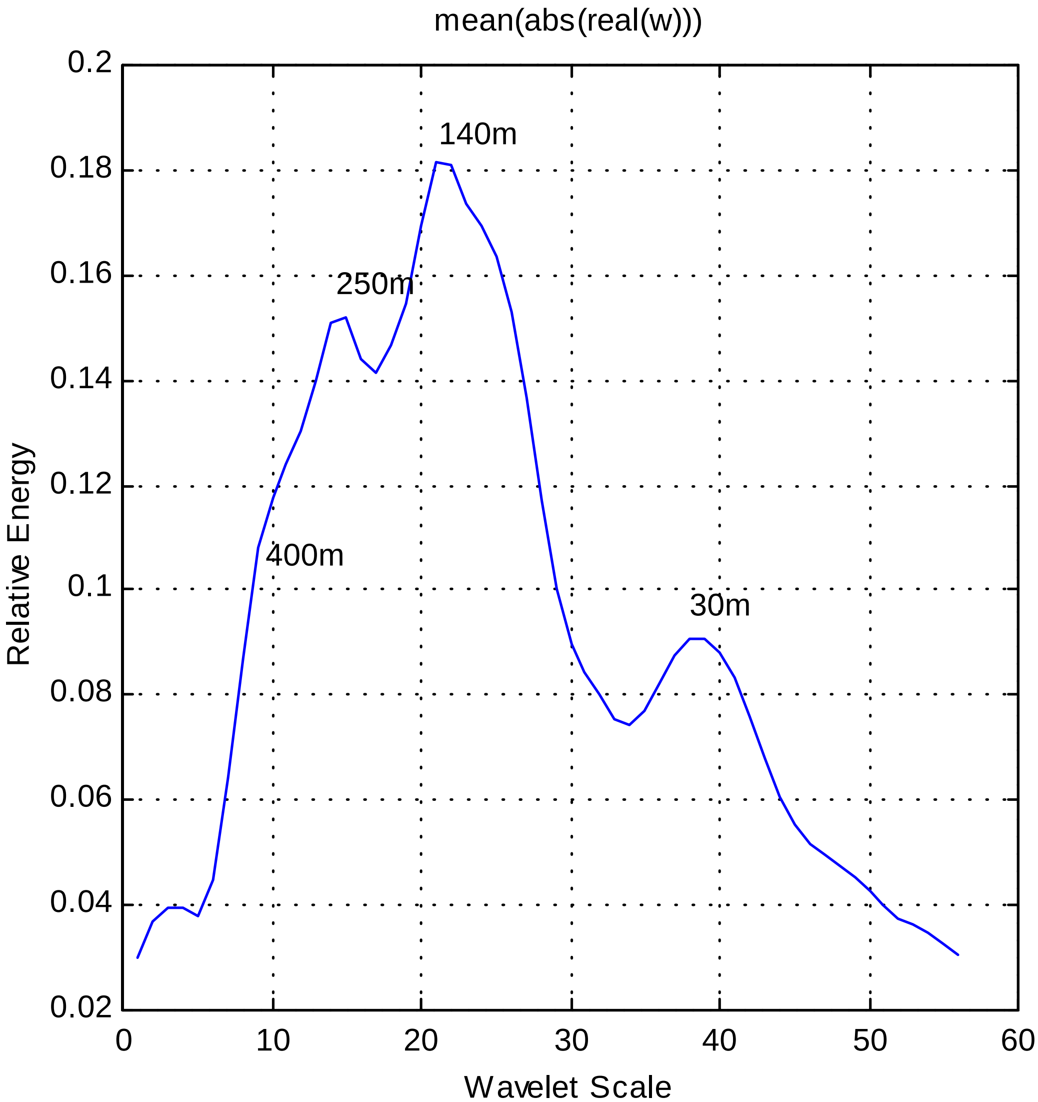
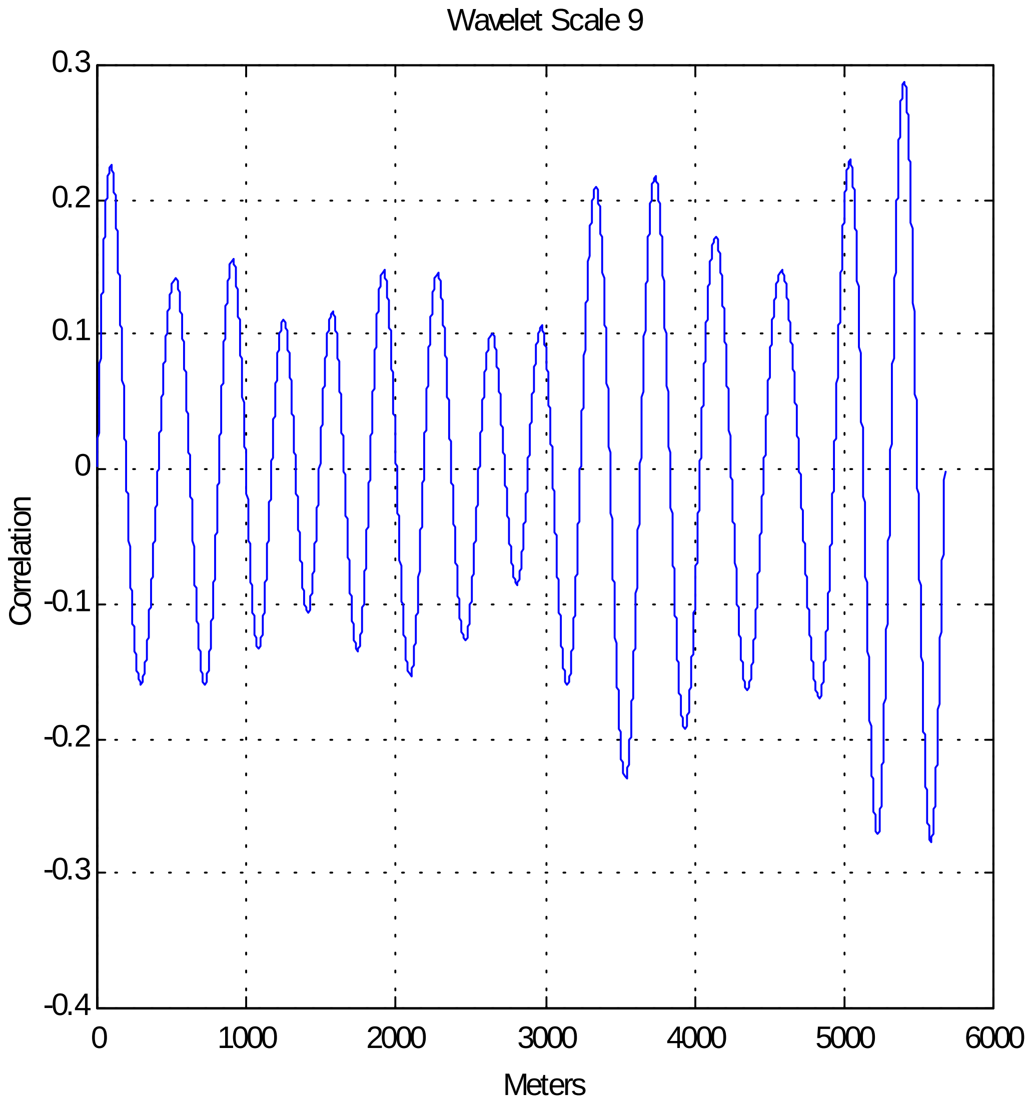
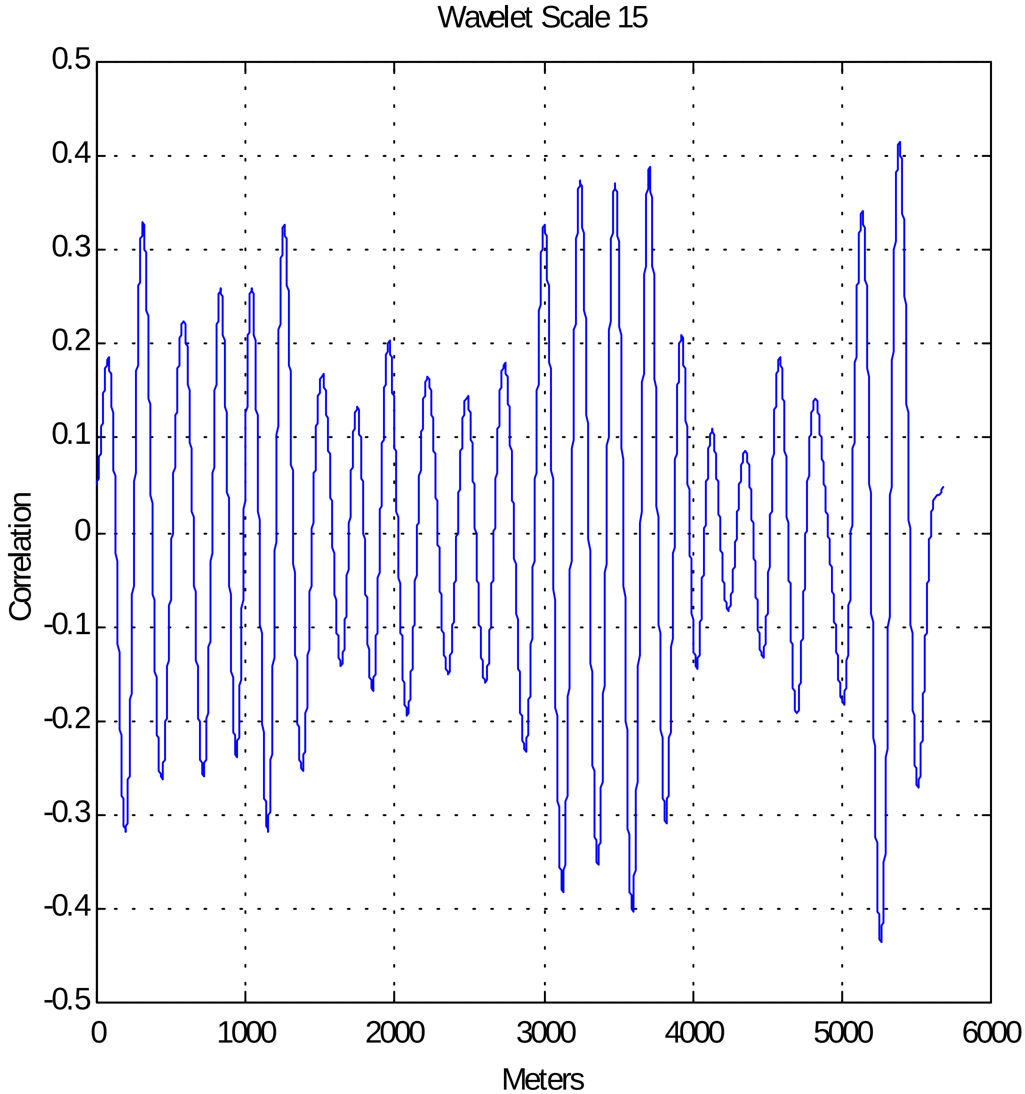

mean(abs(real(w)))
Relative Energy
Wavelet Scale
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
10
20
30
40
50
60
140m
250m
400m
30m

Figure 3



Wavelet Scale 9
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
0
1000
2000
3000
4000
5000
6000
Meters
Correlation

Figure 4



Wavelet Scale 15
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Correlation
0
1000
2000
3000
4000
5000
6000
Meters

Figure 5

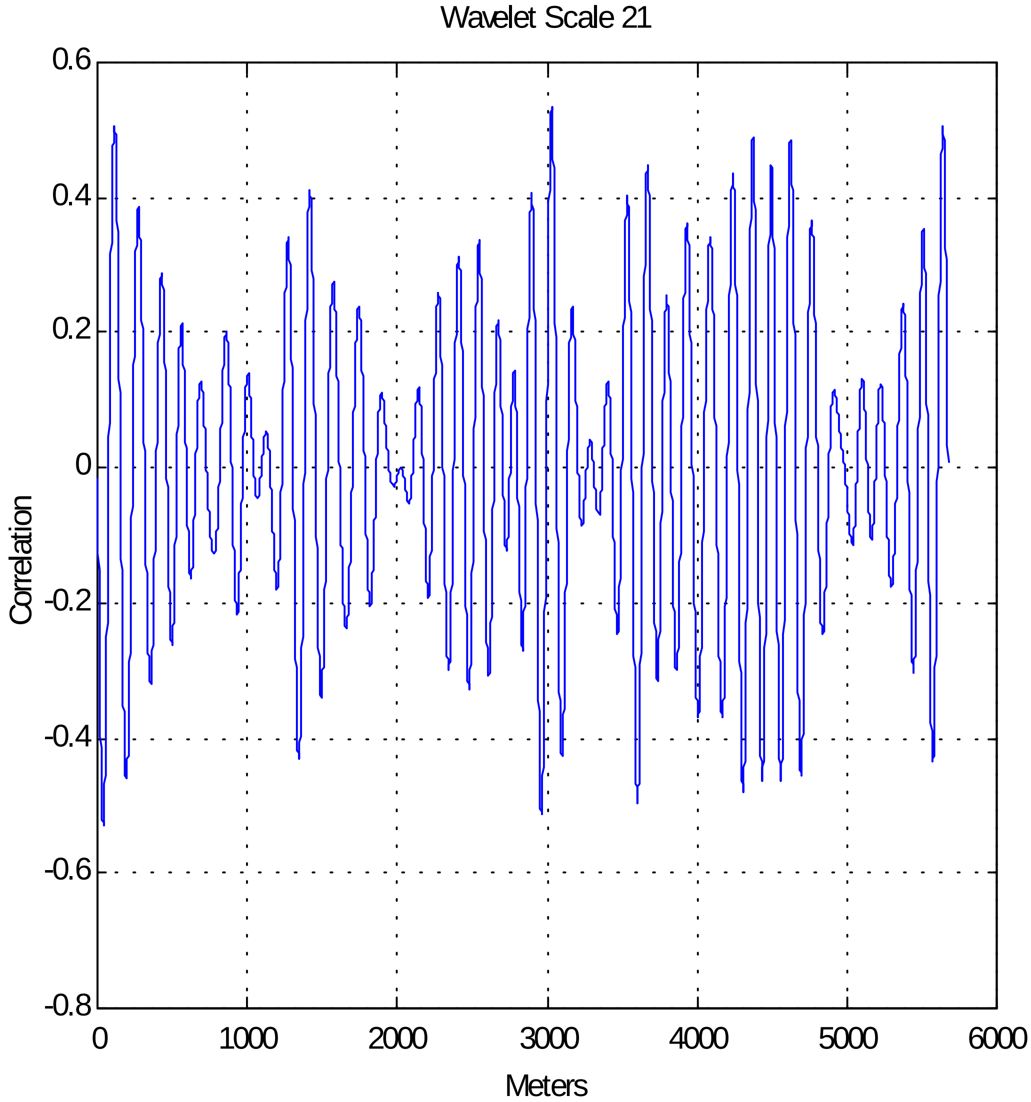
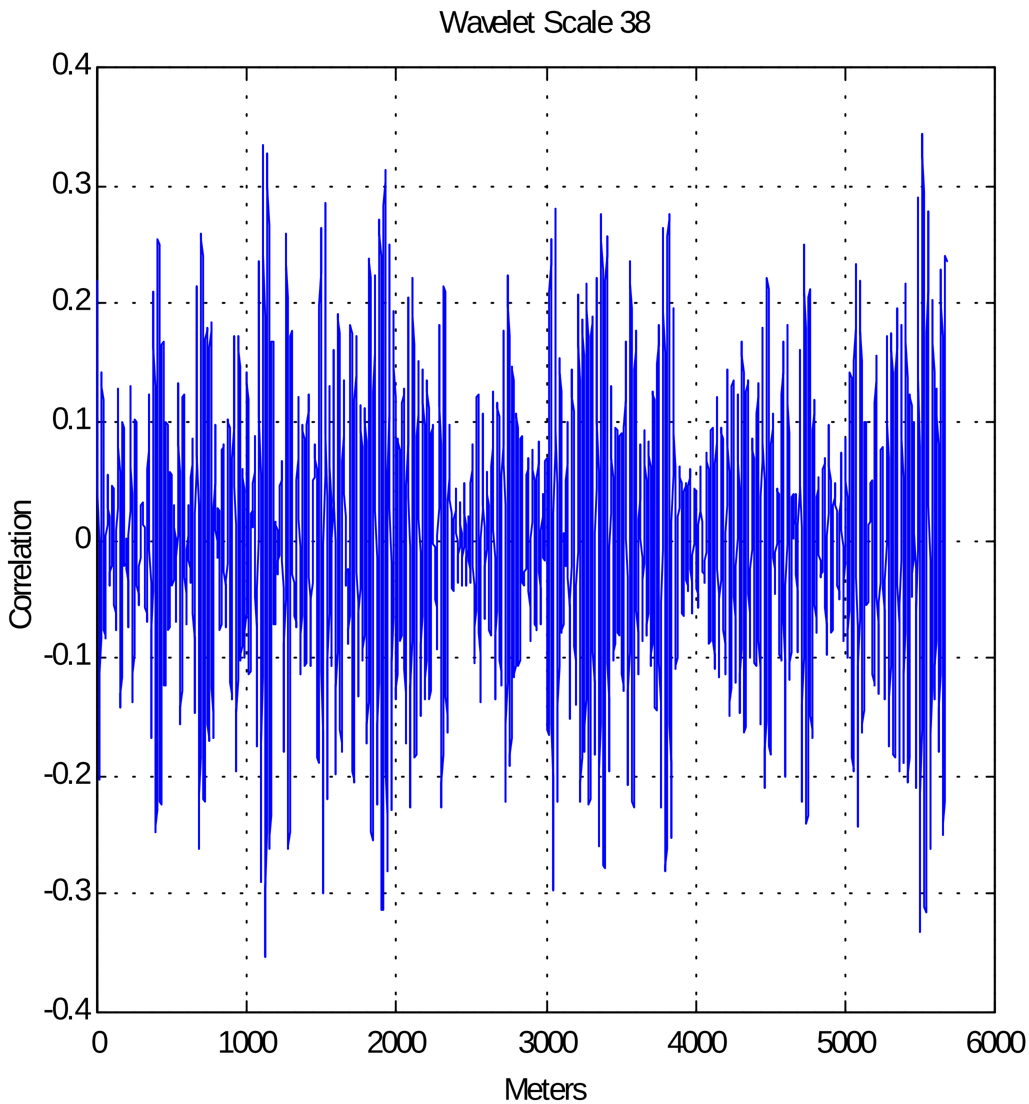

Wavelet Scale 21
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Correlation
0
1000
2000
3000
4000
5000
6000
Meters

Figure 6



Wavelet Scale 38
Correlation
Meters
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
0
1000
2000
3000
4000
5000
6000

Figure 7

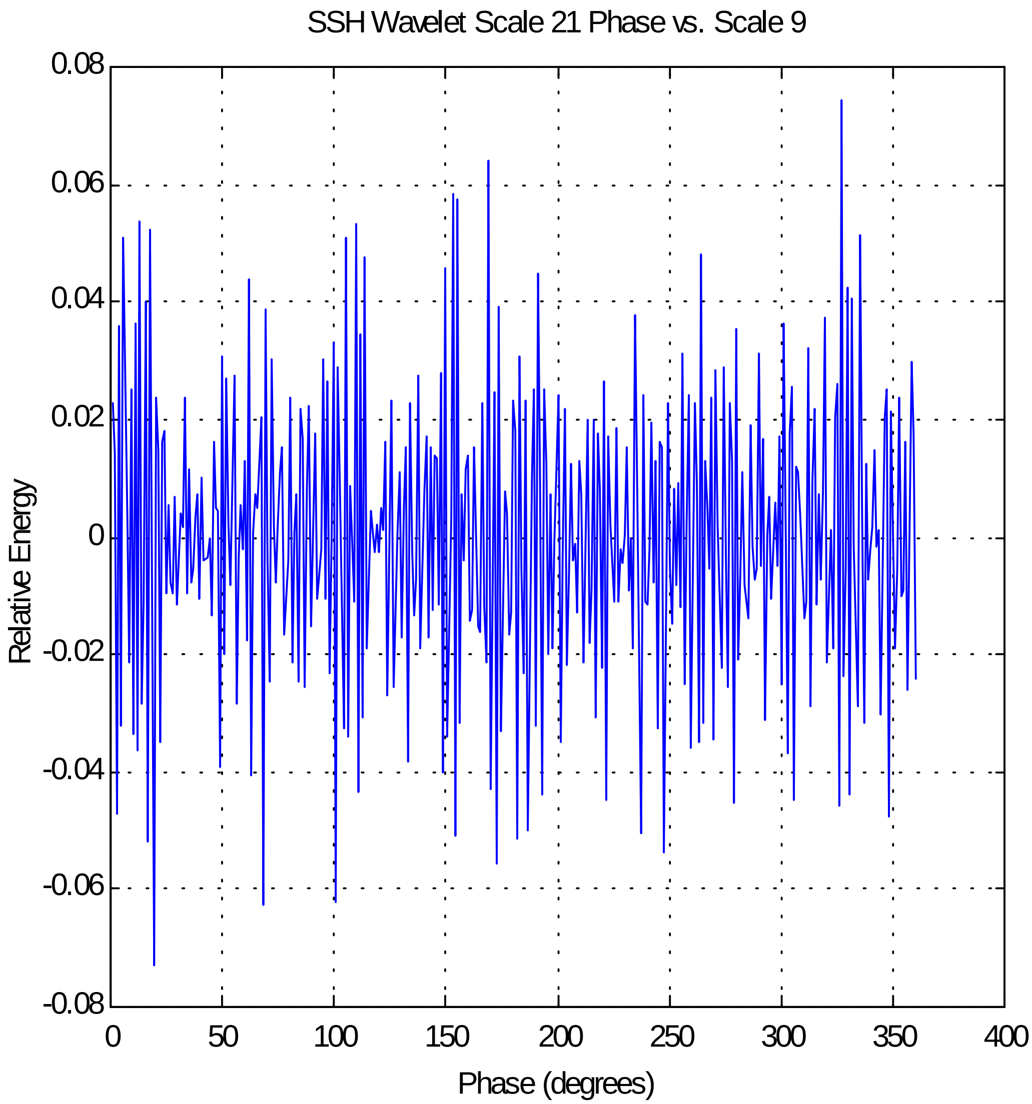

SSH Wavelet Scale 21 Phase vs. Scale 9
Relative Energy
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
0
50
100
150
200
250
300
350
400
Phase (degrees)

Figure 8

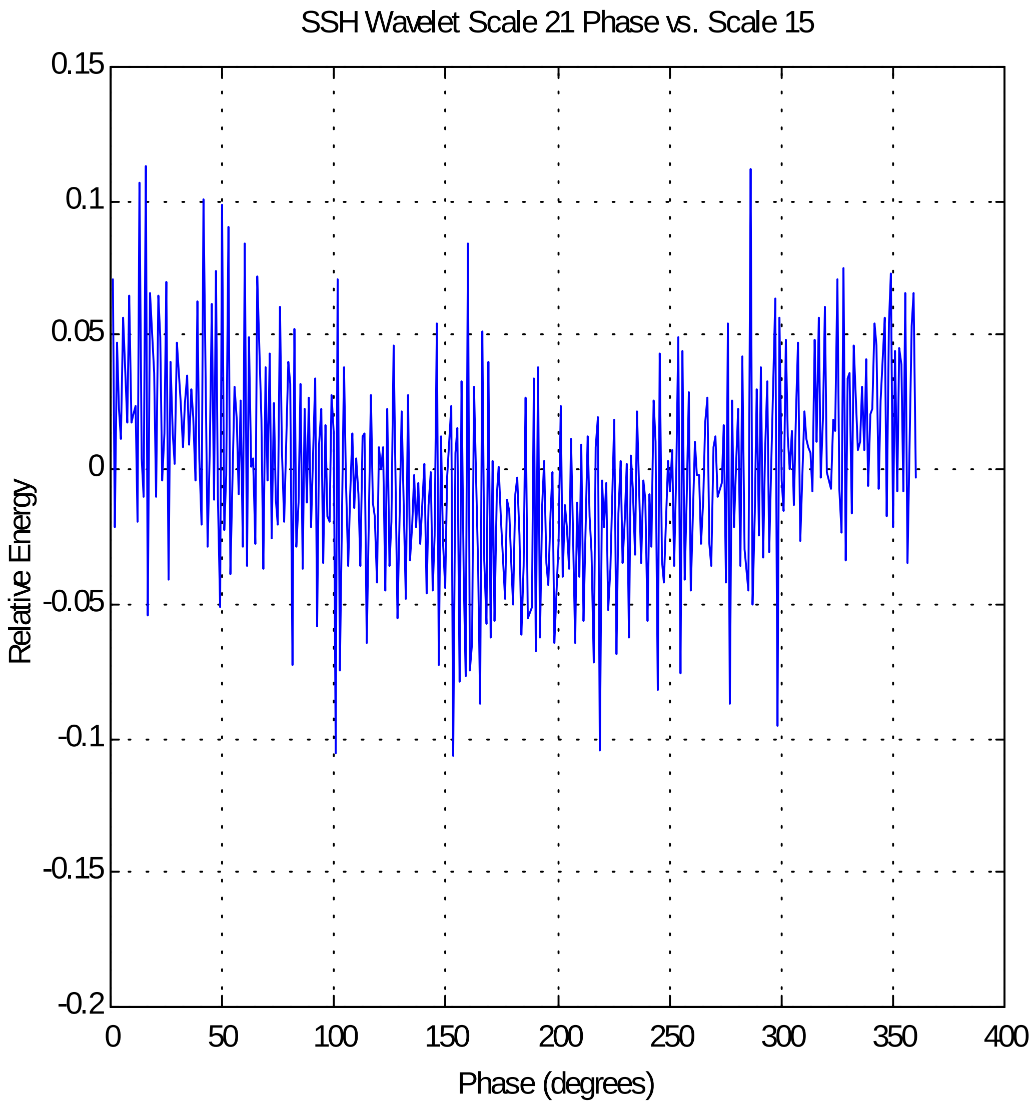
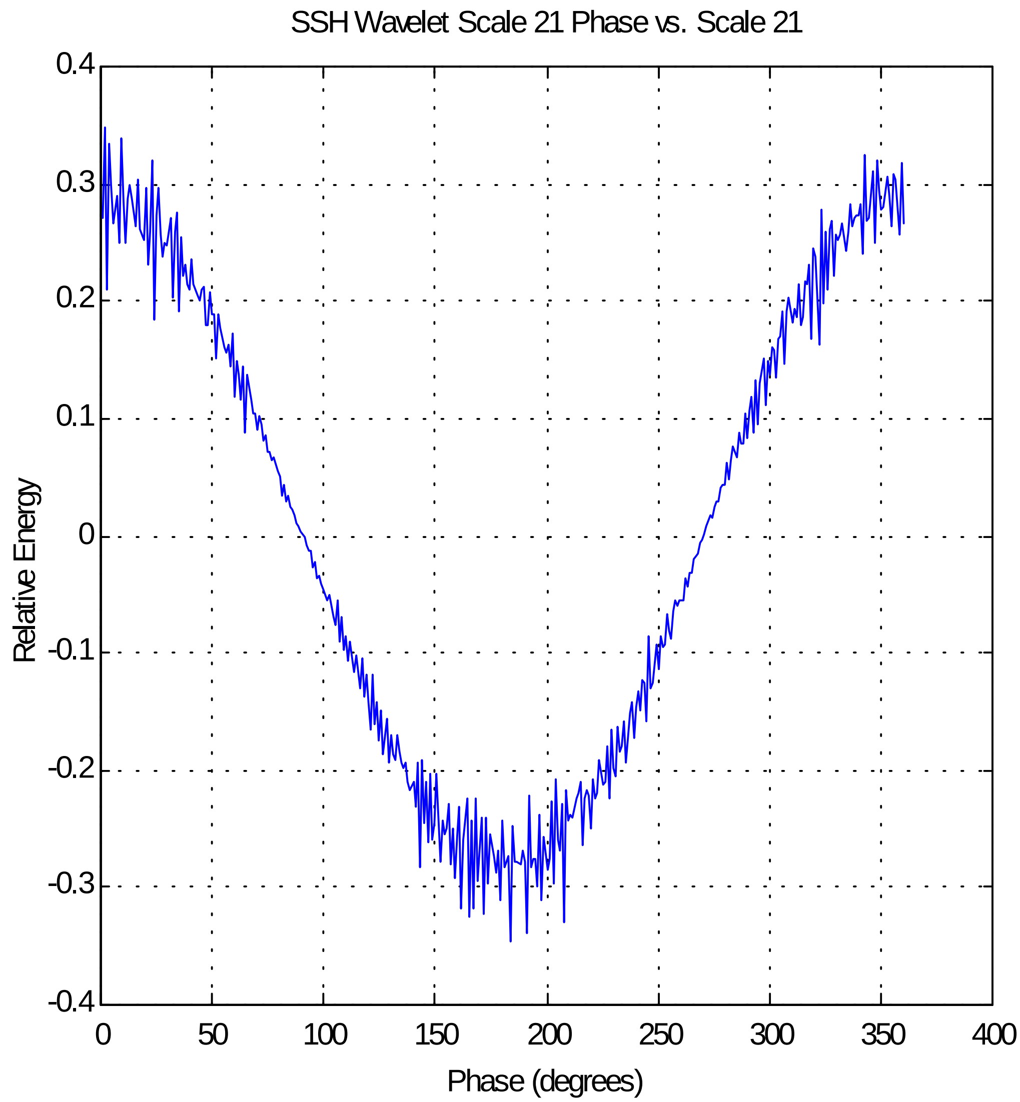

SSH Wavelet Scale 21 Phase vs. Scale 15
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
Relative Energy
0
50
100
150
200
250
300
350
400
Phase (degrees)

Figure 9



SSH Wavelet Scale 21 Phase vs. Scale 21
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
Relative Energy
0
50
100
150
200
250
300
350
400
Phase (degrees)

Figure 10

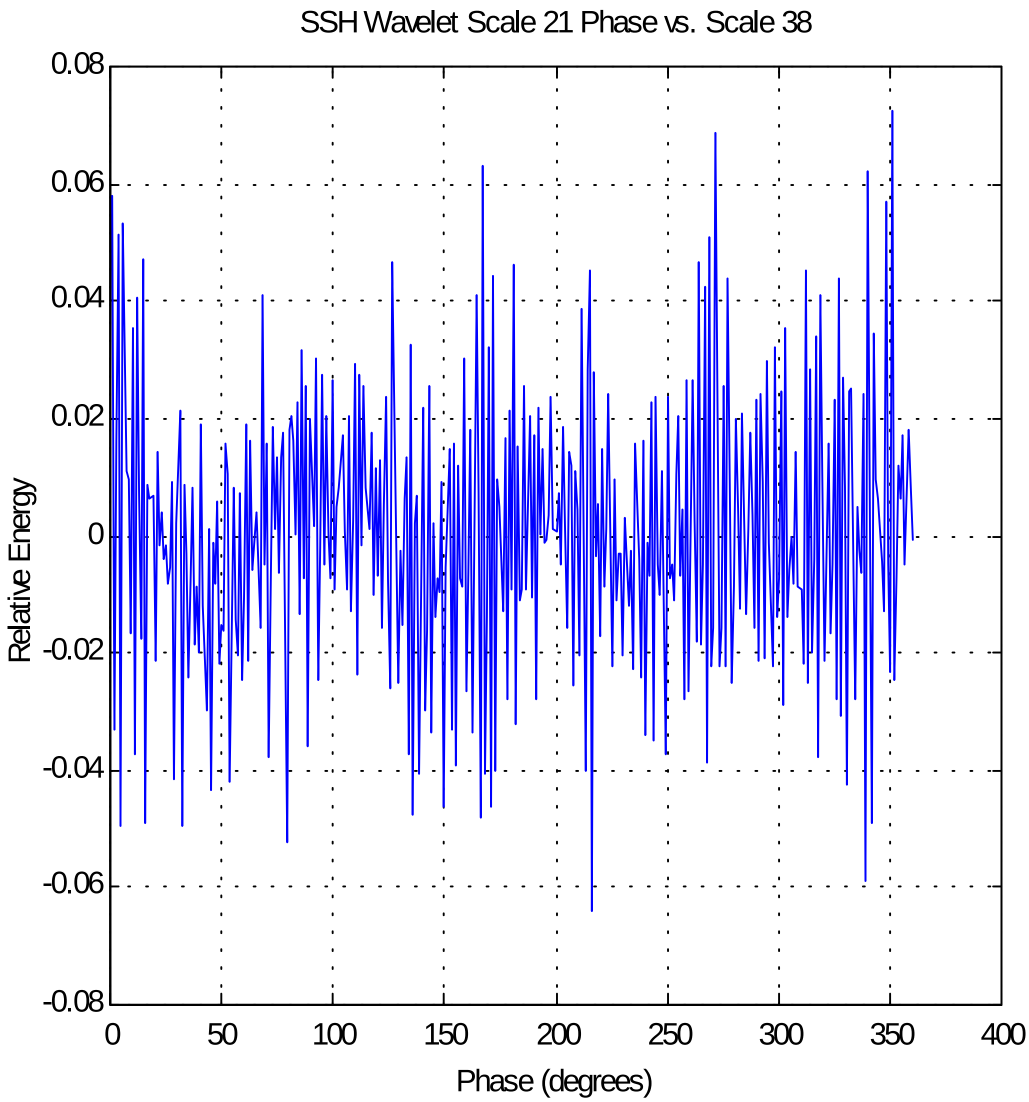

SSH Wavelet Scale 21 Phase vs. Scale 38
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
Relative Energy
0
50
100
150
200
250
300
350
400
Phase (degrees)

Figure 11

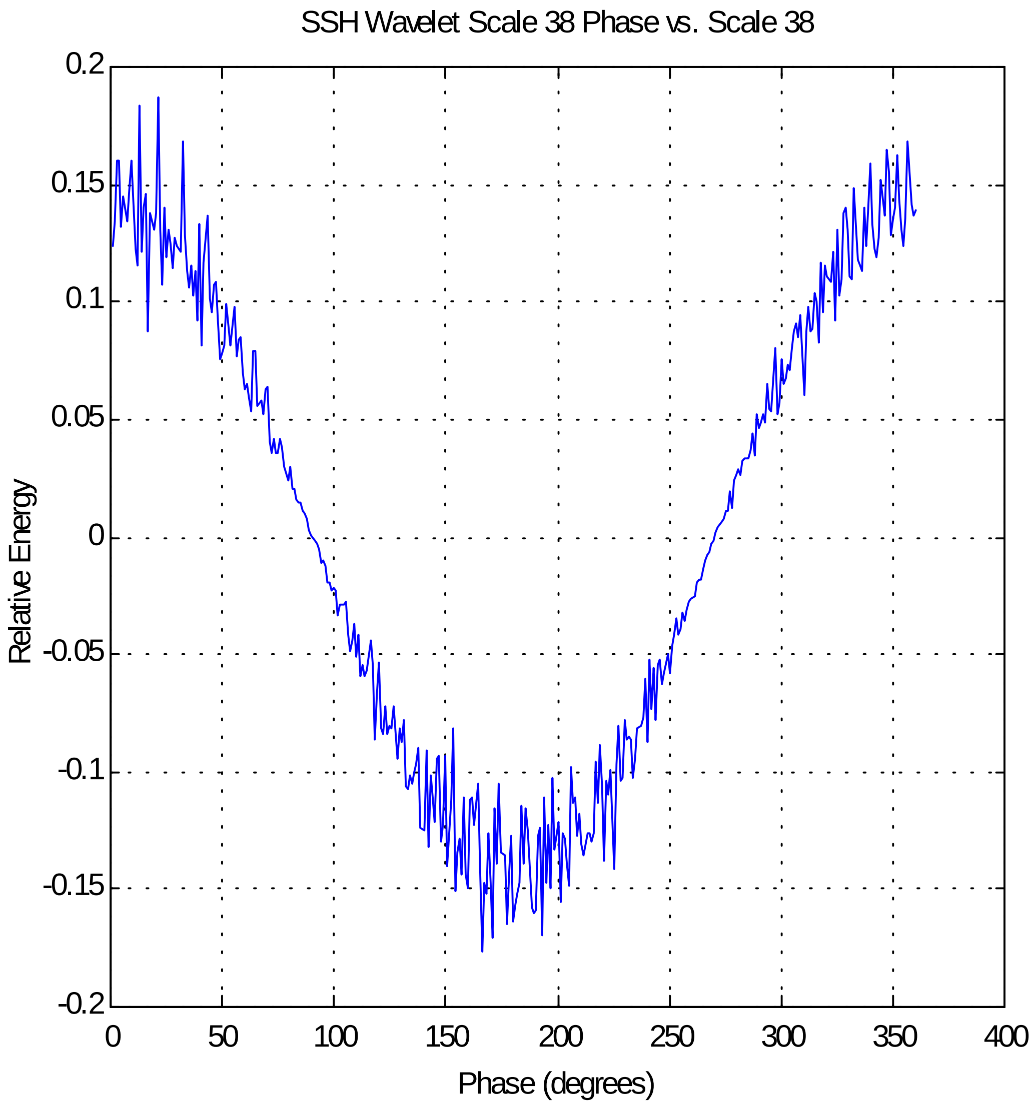

SSH Wavelet Scale 38 Phase vs. Scale 38
Relative Energy
Phase (degrees)
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
0
50
100
150
200
250
300
350
400

Figure 12

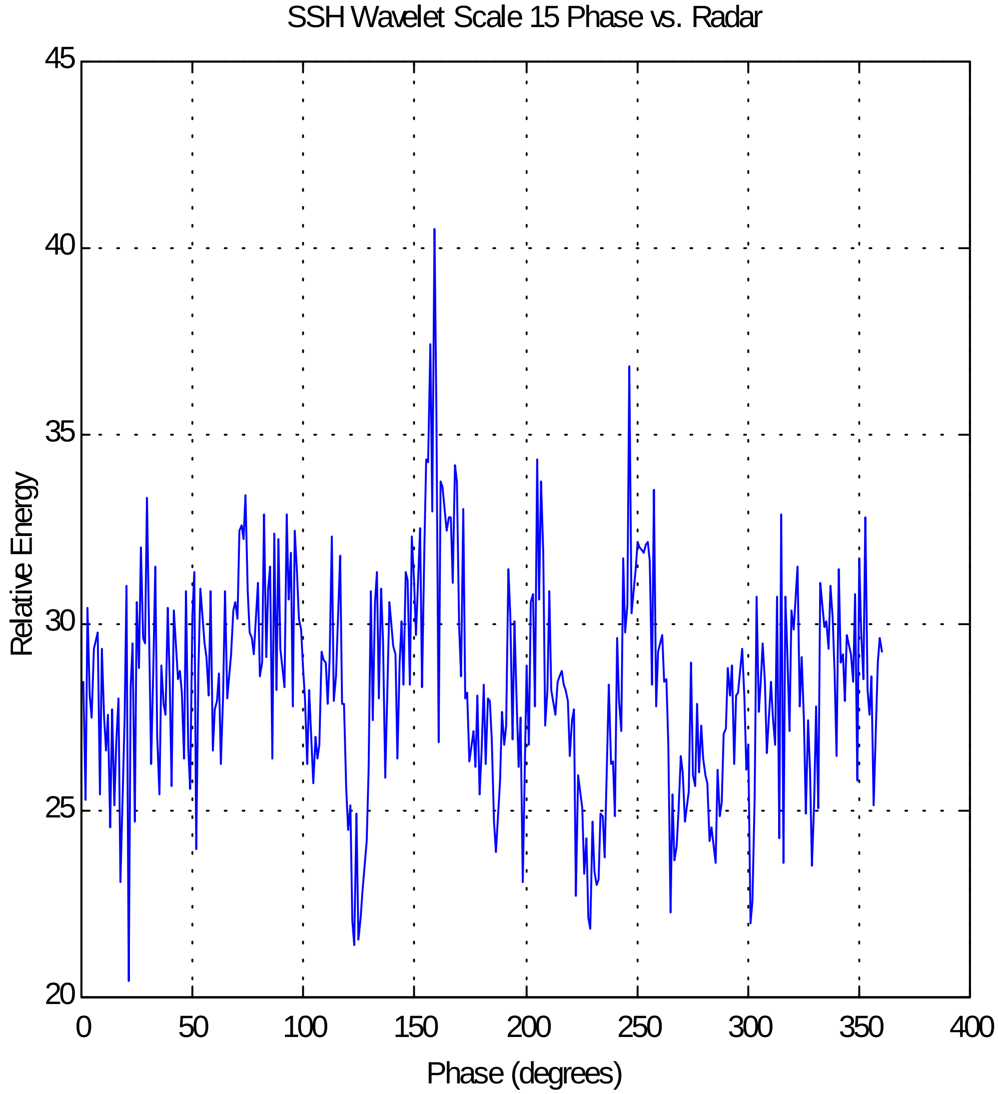

SSH Wavelet Scale 15 Phase vs. Radar
Relative Energy
Phase (degrees)
45
40
35
30
25
20
0
50
100
150
200
250
300
350
400

Figure 13

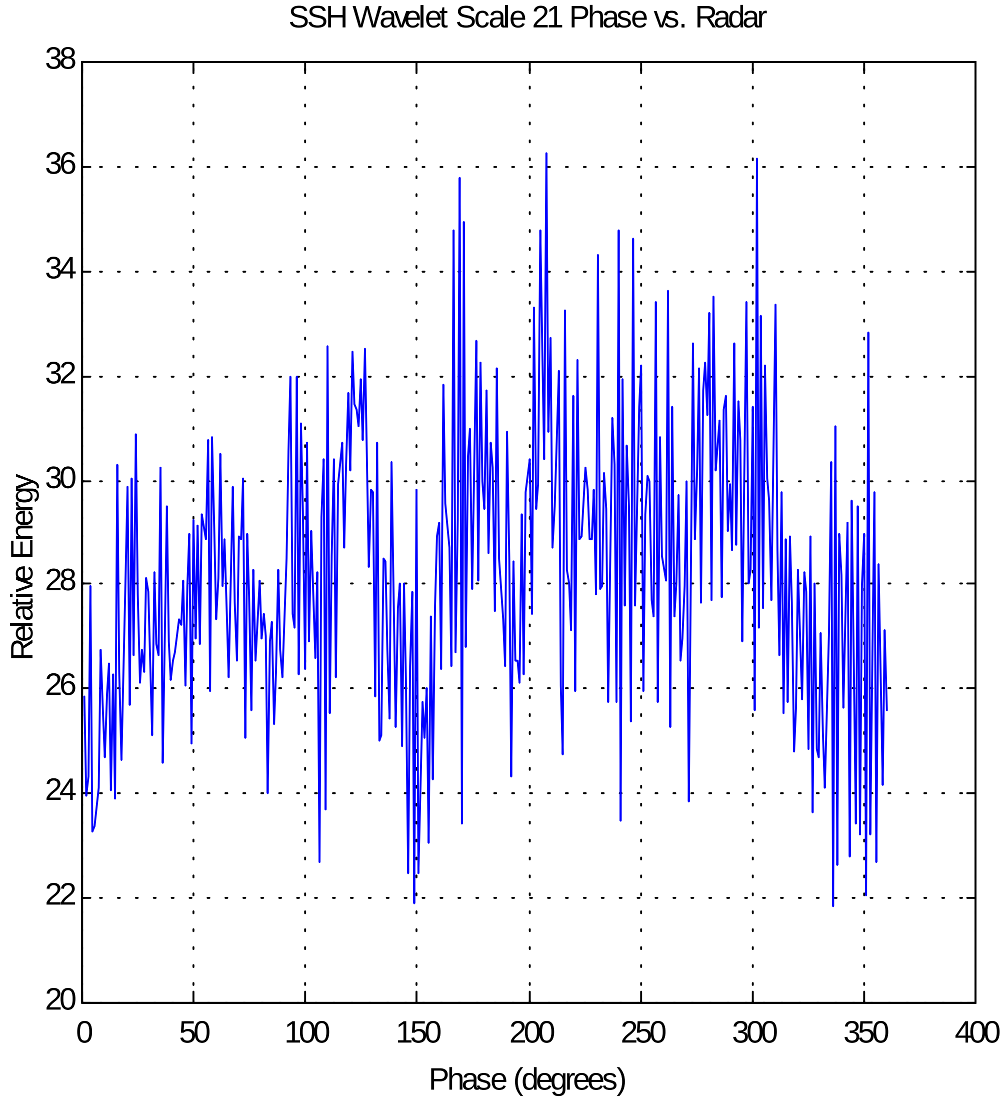

SSH Wavelet Scale 21 Phase vs. Radar
Relative Energy
Phase (degrees)
38
36
34
32
30
28
26
24
22
20
0
50
100
150
200
250
300
350
400

Figure 14

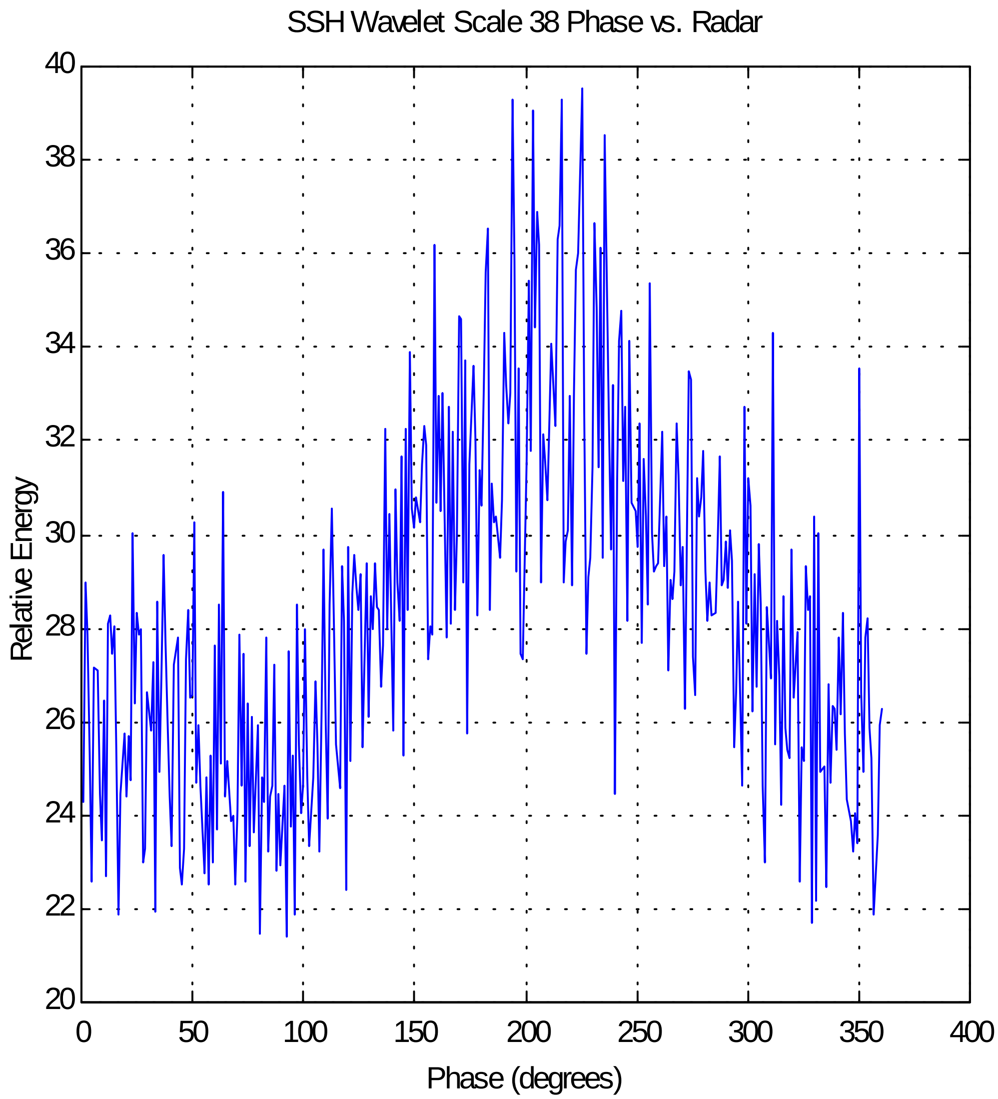
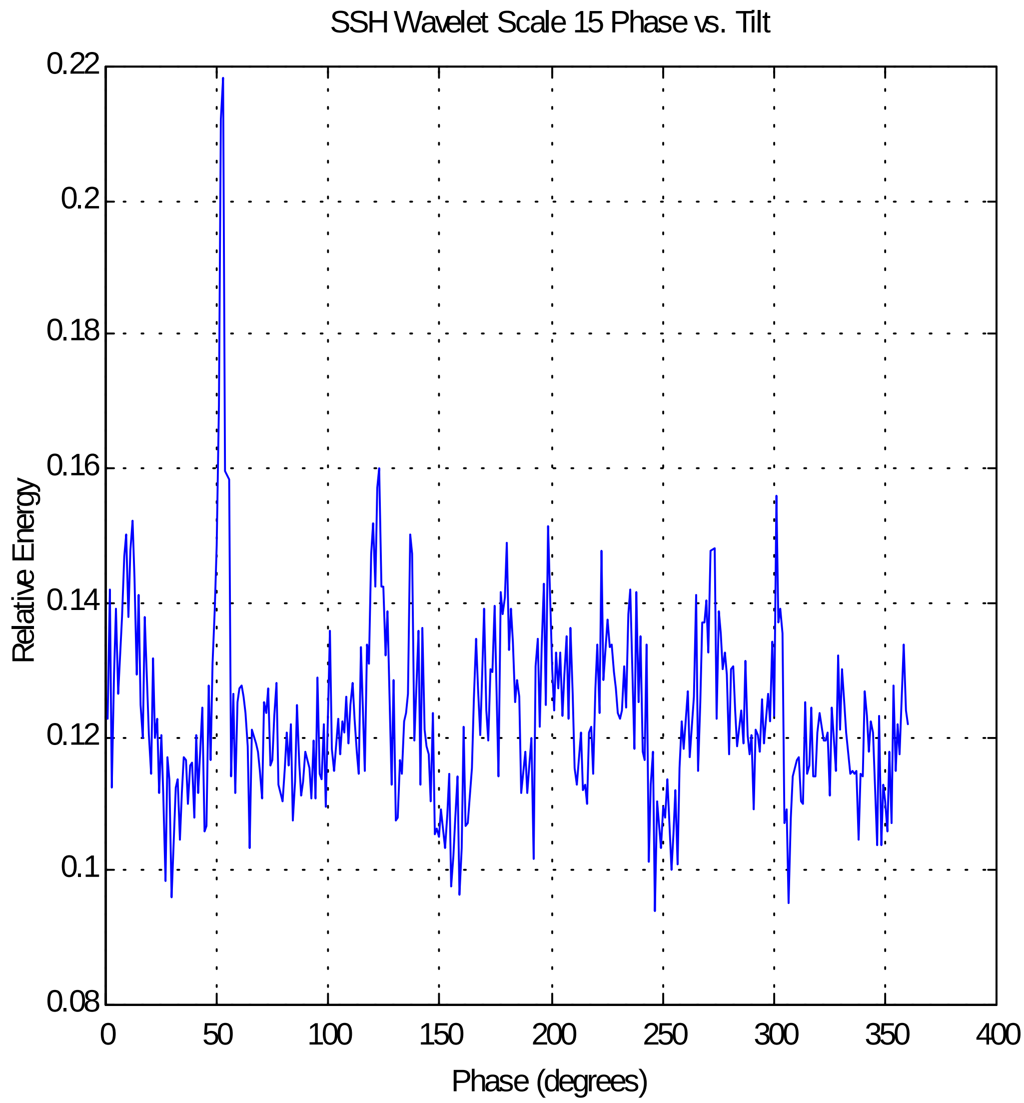

SSH Wavelet Scale 38 Phase vs. Radar
Relative Energy
Phase (degrees)
40
38
36
34
32
30
28
26
24
22
20
0
50
100
150
200
250
300
350
400

Figure 15



SSH Wavelet Scale 15 Phase vs. Tilt
Relative Energy
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0
50
100
150
200
250
300
350
400
Phase (degrees)

Figure 16

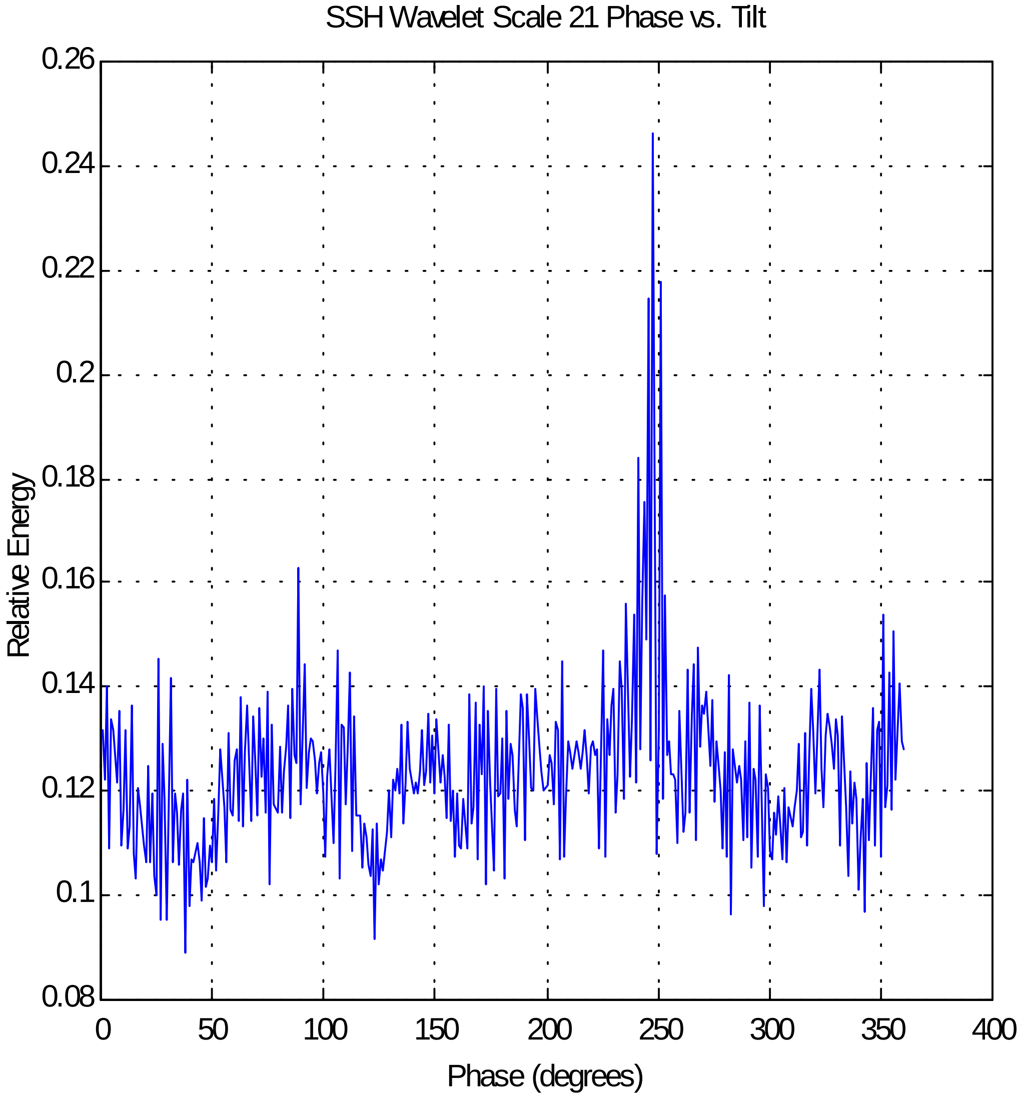
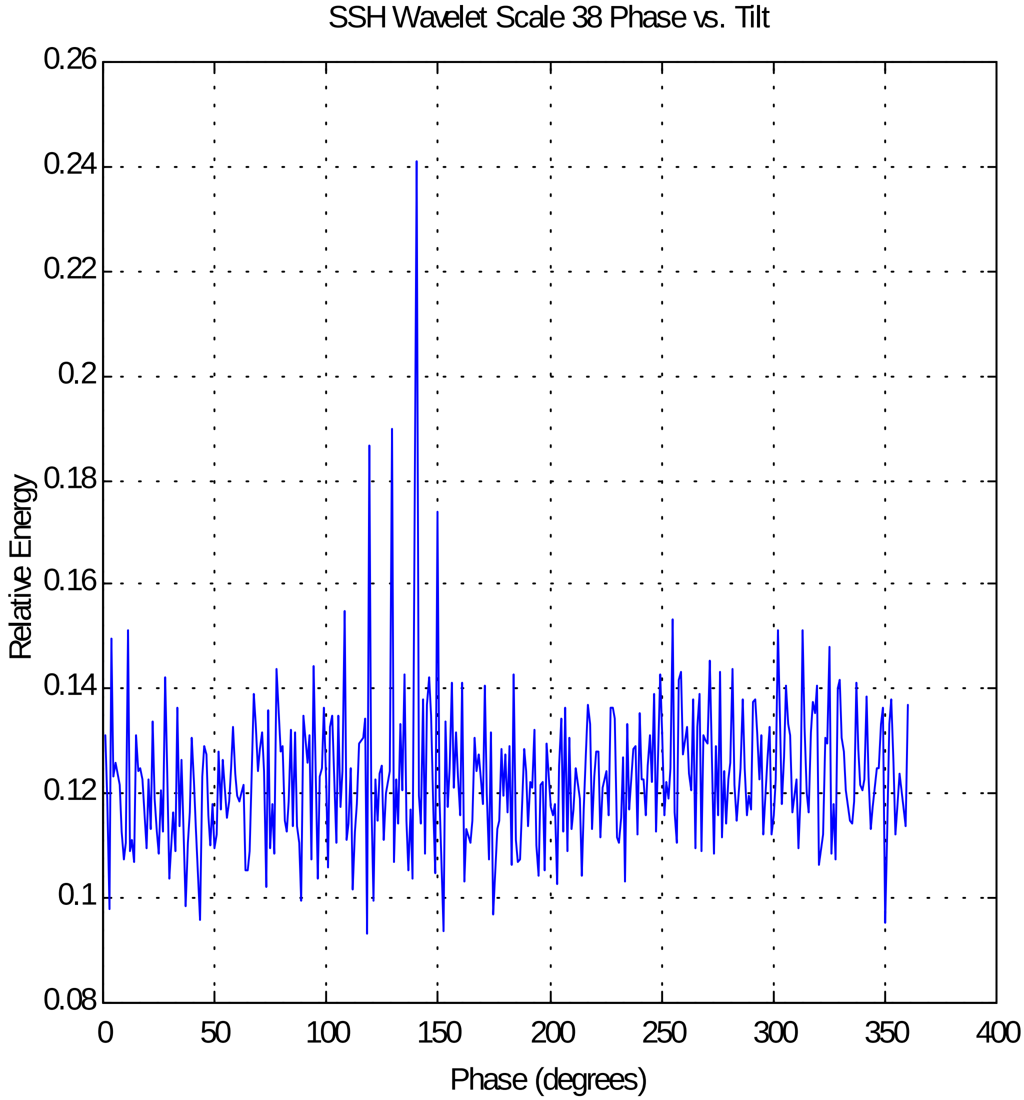

SSH Wavelet Scale 21 Phase vs. Tilt
Relative Energy
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0
50
100
150
200
250
300
350
400
Phase (degrees)

Figure 17



SSH Wavelet Scale 38 Phase vs. Tilt
Relative Energy
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0
50
100
150
200
250
300
350
400
Phase (degrees)

Figure 18

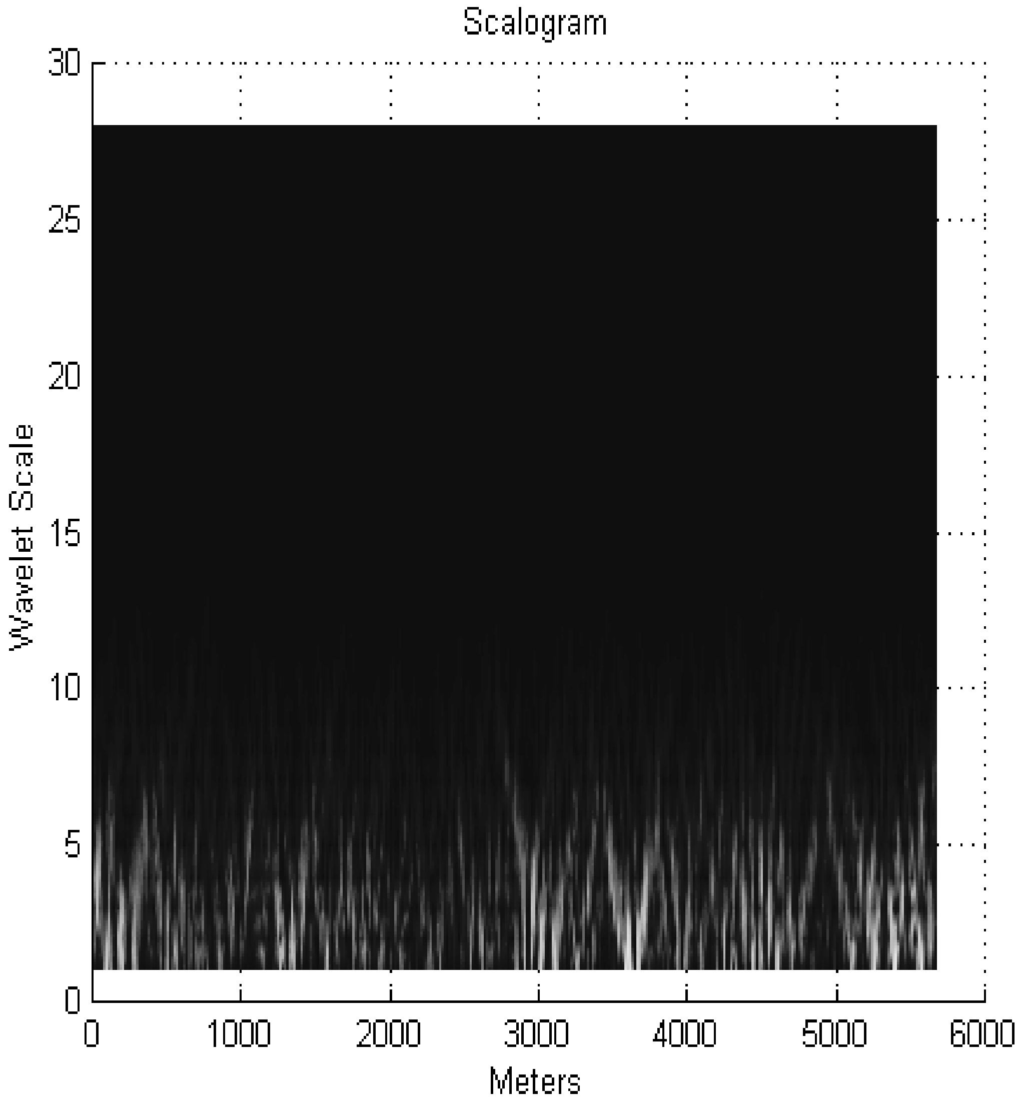

Scalogram
Wavelet Scale
Meters
30
25
20
15
10
5
0
0
1000
2000
3000
4000
5000
6000

Figure 19

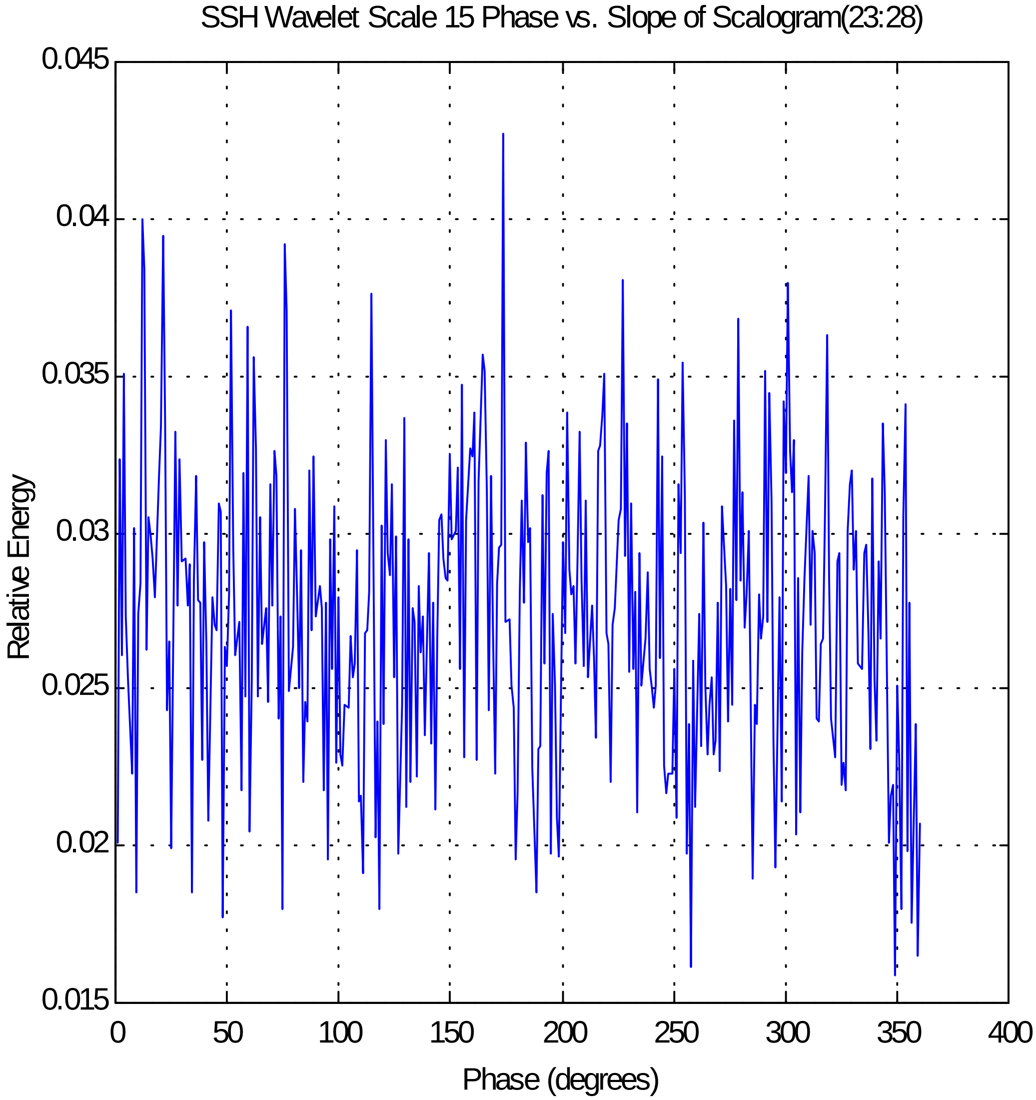

SSH Wavelet Scale 15 Phase vs. Slope of Scalogram(23:28)
0.045
0.04
0.035
0.03
0.025
0.02
0.015
Relative Energy
0
50
100
150
200
250
300
350
400
Phase (degrees)

Figure 20

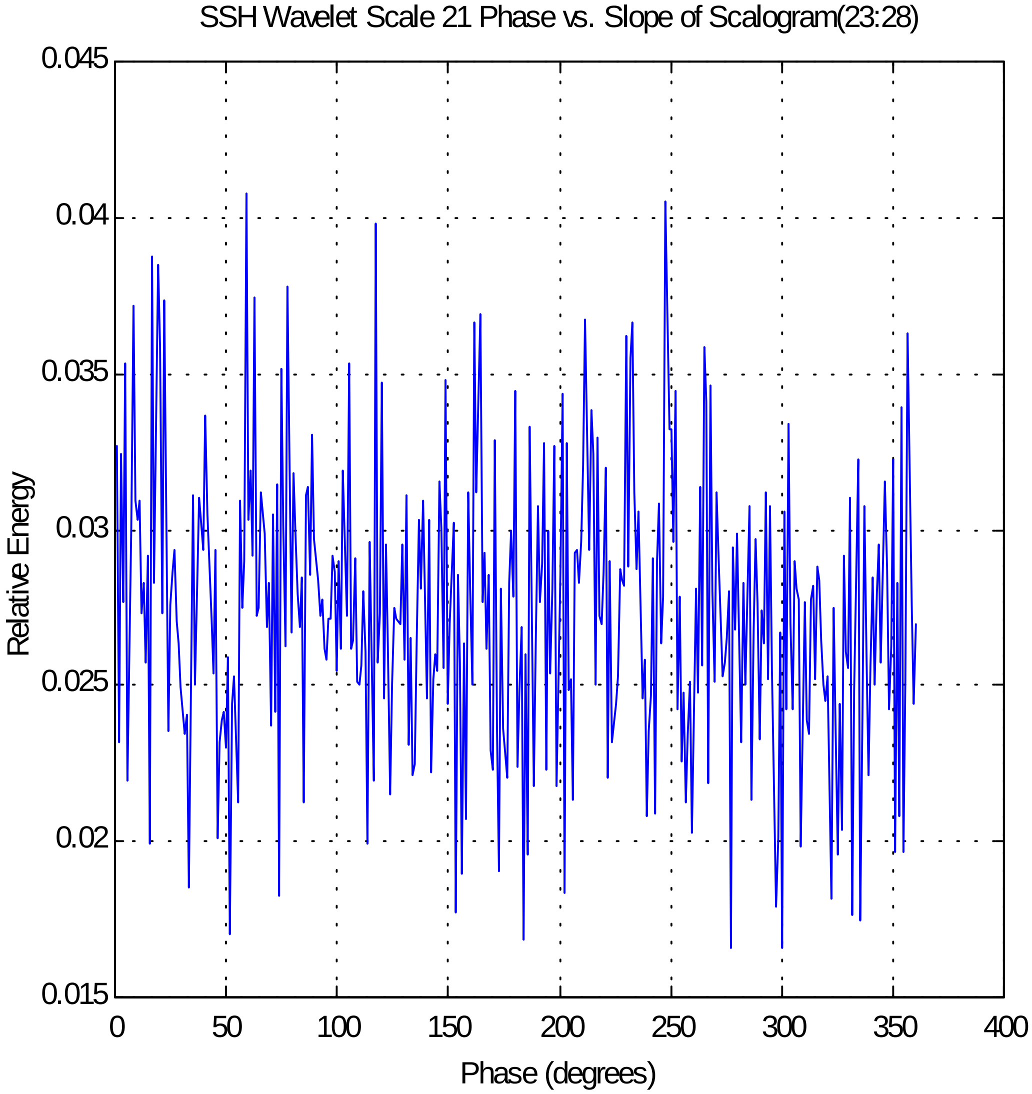
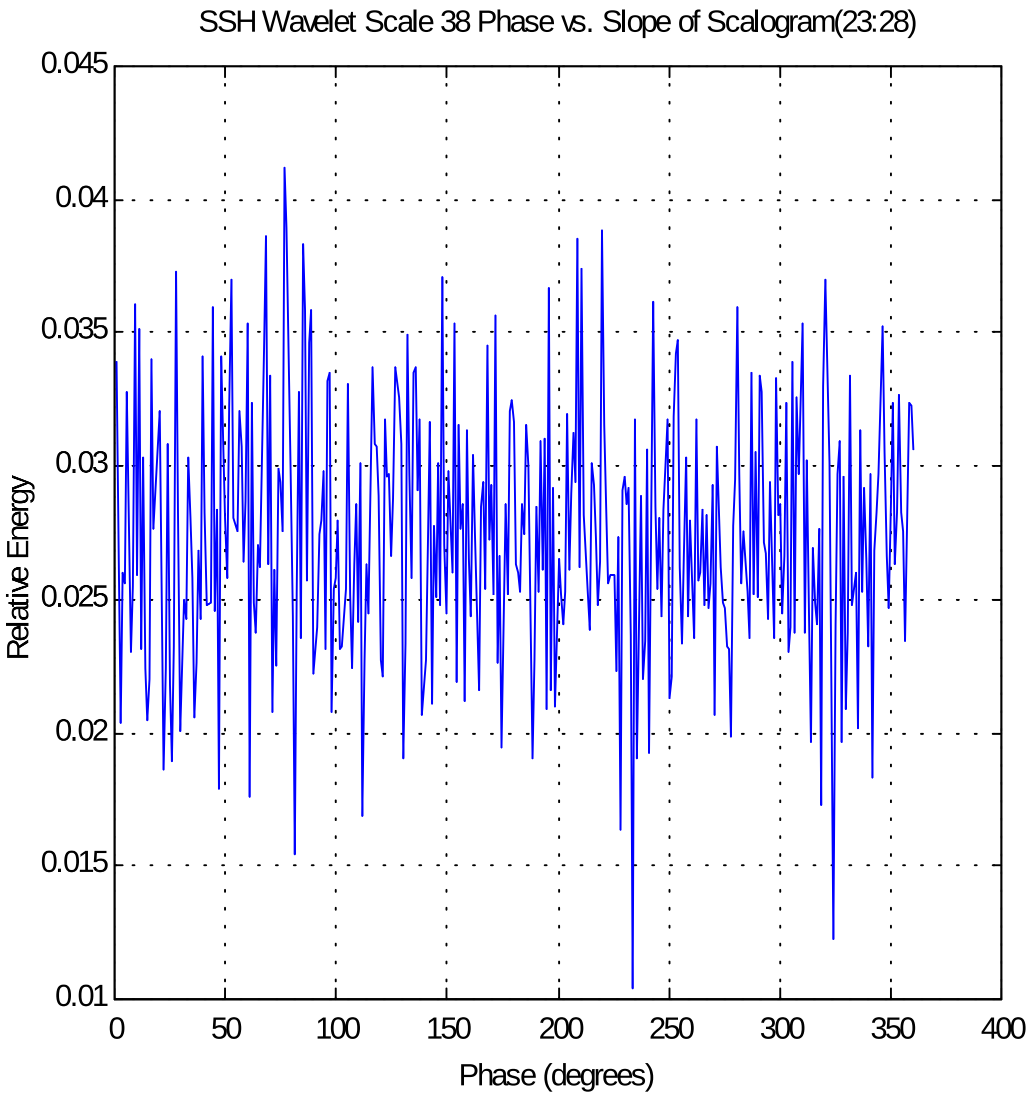

SSH Wavelet Scale 21 Phase vs. Slope of Scalogram(23:28)
Relative Energy
Phase (degrees)
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0
50
100
150
200
250
300
350
400

Figure 21



SSH Wavelet Scale 38 Phase vs. Slope of Scalogram(23:28)
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
Relative Energy
0
50
100
150
200
250
300
350
400
Phase (degrees)

Figure 22